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Full agreement and the provision of threshold public goods

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Abstract: The experimental evidence suggests that groups are inefficient at providing threshold public goods. This inefficiency appears to reflect an inability to coordinate over how to distribute the cost of providing the good. So, why do groups not just split the cost equally? We offer an answer to this question by demonstrating that in a standard threshold public good game there is no collectively rational recommendation. We also demonstrate that if full agreement is required in order to provide the public good then there is a collectively rational recommendation, namely, to split the cost equally. Requiring full agreement may, therefore, increase efficiency in providing threshold public goods. We test this hypothesis experimentally and find support for it.

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1. Introduction

A threshold public good is a public good provided if and only if contributions reach a certain threshold. The classic example would be a capital fundraising project where, say, $1 million is needed to build a new school, cancer unit or theatre (Andreoni 1998). The potential applications of the threshold public good concept are, however, far more general than this archetypal example (e.g. Hardin 1982; Taylor and Ward 1982; Hampton 1987). For instance, the fixed costs associated with running any charity, or other group activity, require a minimum, and often quite large, amount be reached to make the activity viable. It is crucial, therefore, to understand the conditions under which threshold public goods can be efficiently provided.

The provision of threshold public goods does not generate the tension between individual rationality and group outcomes typically associated with public goods (Bagnoli and Lipman 1989). In particular, there are Nash equilibria where the good is produced at the efficient level. Financing the public good does, however, require people to solve a non-trivial coordination problem, because they must coordinate on how to distribute the cost of providing the public good. Experimental evidence suggests that groups are not good at solving this problem; the success rate of providing threshold public goods is typically around 40 to 60 percent, even after experience (Croson and Marks 2000). Such low success is inefficient and potentially very costly to the group.

This level of inefficiency is intriguing when one takes into account a seemingly obvious solution to the coordination problem, namely, split the cost of providing the good equally. We know that groups can coordinate well when there is a focal point that aids coordination (Schelling 1960; Mehta et al. 1994; Bardsley et al. 2010). For some reason the 'split the cost equally' focal point is not enough, in itself, to help groups coordinate in standard threshold public good games (Issac, Schmidtz and Walker 1989). This is most powerfully illustrated by (Croson and Marks 2001) who find that recommending the equal split did not increase success rates above 60%.[1]

This raises two fundamental questions: (a) why is the seemingly obvious focal point of 'split the cost equally' not sufficient to enable coordination in a standard threshold public good game, and (b) is there any way to encourage groups to successfully coordinate using this focal point. Answering these two questions is fundamental in understanding the

[1] In more detail, they found that recommending the equal split had no effect on success rates in a symmetric threshold public good game (see below for a definition of symmetry). It did significantly increase success rates in an asymmetric treatment, but only to the level seen in the symmetric treatments, from 48% to 57% success.

conditions under which threshold public goods can be efficiently provided. In this paper we offer an answer to both questions. In doing so, we also add to the emerging literature on focal points in asymmetric coordination games (Crawford et al. 2008; Isoni et al. 2013).

In explaining our approach we begin by noting that the standard threshold public good game sees group members make individual contributions towards the public good. All, therefore, an individual decides, or can communicate, is her contribution, e.g. ‘I will contribute $15’. In applications, one often observes the potential for more complex strategies. For instance, a group member may suggest what everyone in the group should do, e.g. ‘we should each contribute $15’. Alternatively, a group member may make their contribution conditional on others, e.g. ‘I will contribute $15 if everyone else contributes $15’. Refined strategies, like these, have two effects on the way group members interact. First, they are a means for individuals to *communicate* with each other because an individual can say what he or she thinks others should do. Second, they may change the rules governing public good provision because *agreement* is needed when contributions are made conditional on what others will do.

Both communication and a need for agreement can change the nature of interaction. We will demonstrate that the need for agreement is particularly crucial. This may seem strange given that the direct consequence of a need for agreement is to make the group’s task *more* difficult. Group members not only need to be individually willing to contribute enough to finance the good but also need to agree with each other on what they should contribute. This direct, negative effect can, however, be outweighed by indirect, positive effects. In particular, the need for agreement has two positive consequences: (i) it increases the criticality of each individual’s decision, while (ii) offering a guarantee that others cannot exploit a willingness to contribute. Prior studies suggest that a perception of increased criticality increases contributions (Au, Chen and Morita 1998; De Cremer and van Dijk 2002). We also know that the fear of exploitation discourages contributions (e.g. Isaac et al. 1989; Rapoport and Eshed-Levy 1989).

A need for agreement can only succeed, though, if group members have the means and desire to coordinate. Increased criticality, for instance, can only work if group members know what is expected of them. This is much more likely if there is a focal point around which to coordinate. In short, criticality makes every individual feel as though their decision is *necessary* in order to achieve a successful outcome, while the existence of a focal point makes it *possible* for the group members to successfully coordinate. As already discussed, however, evidence from the standard threshold public good game does not seem consistent with a strong focal point. Will, therefore, group members be able to reach agreement?

To formally analyze the consequences of communication and agreement we apply the seminal theory of focal points due to Sugden (1995). In the theory, a focal point is captured by the concept of a collectively rational recommendation. Our main theoretical result can be summarized as follows: (i) in a standard threshold public good game there is no collectively rational recommendation, but (ii) if full agreement is required to provide the public good there is a unique collectively rational recommendation, namely, to split the cost equally. This result explains why members find it difficult to finance the public good in a standard threshold public good game. It also suggests that a requirement for full agreement will help groups coordinate and successfully finance the good, because it increases the prominence of the equal split focal point.

We test experimentally the hypothesis that a need for agreement increases efficiency in providing the public good and find support for it. Our experimental design allows us to distinguish whether communication or the need for agreement is more important in aiding coordination, and we come down strongly on the side of the need for agreement. Indeed, communication appears to make no difference to success in providing the public good. By contrast, a need for agreement increases success, provided subjects are sufficiently experienced. The finding that people can successfully coordinate when they need to reach agreement is consistent with the evidence that people can coordinate in ‘matching games’ because of team reasoning or collective rationality (Schelling 1960; Sugden 1993; Mehta et al. 1994; Bacharach 2006, Bardsely et al. 2010).

Recall that the need for agreement has two indirect benefits. The discussion so far has focussed on the benefit of increased criticality. We finish the introduction by looking in more detail at the benefit of avoiding exploitation. A need for full agreement gives each group member veto power over how the public good will be financed. This means that a member cannot be ‘surprised’ by the contributions of others. Put another way, a member cannot be ‘unexpectedly’ exploited by others. This can give increased confidence to contribute by solving the assurance problem (Issac et al. 1989). It does not, however, rule out exploitation. In particular, if endowments are asymmetric then the equal split focal point is commonly seen as unfair (see van Dijk and Wilke 1993, 1995). Given that all members contribute the same to the public good one can think of those with a high endowment as exploiting those with a low endowment. This creates a tension between the focal point and fairness, or between efficiency and fairness. Indeed, those with a relatively low endowment may shun the equal split focal point.

The notion that focal points can create a tension in games with asymmetric outcomes is not new (Schelling 1960). Relatively few experimental studies, however, have looked at behaviour in asymmetric coordination games.[2] To explore the tension between focal points and fairness in more detail we compare a setting with symmetric endowments to settings with progressively more asymmetric endowments. In the case where full agreement is required, we find that increasing asymmetry has no effect on success of providing the public good. This suggests that subjects were willing to trade efficiency for equity. Isoni et al. (2013) obtain a similar result when looking at tacit bargaining games.[3] This apparent willingness of subjects to trade equity for efficiency demonstrates the power of focal points.

We proceed as follows: In Section 2 we introduce the threshold public good games we shall study. In Section 3 we provide our main theoretical results. In Section 4 we describe our experimental results. In section 5 we conclude. Additional material is provided in an appendix.

2. Threshold public good games

We begin by describing what we shall call the standard type of game. The prior literature has focussed on this type of game when considering simultaneous threshold public good games (e.g. Suleiman and Rapoport 1992, Cadsby et al. 2008). The standard type of game will then be contrasted with three other types of game that progressively differ in the feedback given to players, strategy set, and the payoff function. The differences are summarized in Table 1 and will be explained in more detail below.

In all the games we shall consider there is a set of n players $N = \{1, \dots, n\}$. Each player $i \in N$ is endowed with E_i units of a private good where E_i is some positive integer. If $E_i = E_j$ for all $i, j \in N$ then we say the game is *symmetric*. Otherwise we say that it is asymmetric. There also exist positive integers T and V that we shall refer to respectively as the *threshold* and the individual *value* of the public good. The importance of T and V will

[2] Crawford, Gneezy and Rottenstreich (2008) find that slight asymmetry reduces the power of focal points. Other studies, however, paint a more positive picture. For example, Cooper et al. (1993) and Holm (2000) find that a focal point can help players coordinate in the battle of the sexes game.

[3] In the battle of the sexes game all efficient equilibrium are asymmetric and so focal points may merely aid coordination. In a threshold public good game and bargaining game there can be a focal asymmetric equilibrium (e.g. split the cost equally) and a less focal symmetric equilibrium (e.g. split the cost proportionally). This creates a tension between the focal point and fairness.

become clear shortly. To clarify terminology, a particular game is characterized by two things, the *type* of game – standard, full agreement etc. – and the *set of parameters* of the game – *n, E, T* and *V*.

In a *standard game*, independently and simultaneously all players must decide how much of their endowment to contribute towards a public good. The strategy set, therefore, of any player $i \in N$ is the set of integers $S_i \equiv \{0,1,\ldots,E_i\}$. A strategy profile $(c_1,\ldots,c_n)$ details the strategy of each player, where $c_i \in S_i$ will be called the contribution of player $i \in N$. Let $C = \sum_{i=1}^{n} c_i$ denote total contributions. If total contributions equal or exceed the threshold T then each player receives an additional V units of the private good. We also say that the group was successful in providing the public good. If contributions are below the threshold each contribution is refunded. The payoff of player *i*, given strategy profile $(c_1,\ldots,c_n)$, is, therefore,

$$u_i(c_1,\ldots,c_n) = \begin{cases} E_i - c_i + V & \text{if } C \geq T \\ E_i & \text{otherwise} \end{cases} \tag{1}$$

At the end of the game each player is told total contributions, C, but is not told the individual breakdown of contributions. In a *standard game with feedback* players are informed at the end of the game on the list of individual contributions $c_1,\ldots,c_n$, but all other details remain the same. The difference between a standard game and standard game with feedback was considered by Croson and Marks (1998).

In a *game with communication* the strategy set of a player differs to that of a standard game or standard game with feedback. Independently and simultaneously all players must decide on a *vector of contributions* saying how much they 'suggest' each player should contribute towards the public good. The strategy set of any player $i \in N$ is, therefore, $S^{CG} \equiv S_1 \times \ldots \times S_n$. Strategy profile $(vc_1,\ldots,vc_n)$ details the strategy of each player where $vc_i = (c_{i1},\ldots,c_{in}) \in S^{CG}$ denotes the vector of contributions chosen by player i and c_{ij} is the amount that player *i* 'suggests' player *j* should contribute. Let $c_i = c_{ii}$ be the amount that player *i* is willing to contribute and, as before, let $C = \sum_{j=1}^{n} c_j$ denote total contributions. The payoff function remains the same as in a standard game (see equation (1)), and so, given strategy profile $(vc_1,\ldots,vc_n)$, the payoff of player *i*, is

$$u_i(vc_1,\ldots,vc_n) = \begin{cases} E_i - c_i + V & \text{if } C \geq T \\ E_i & \text{otherwise} \end{cases}$$

Note, that only the value of c_i for all $i \in N$ has any direct bearing on the game. At the end of the game players are, however, informed on the vector of contributions suggested by each player, as well as total contributions. The value of c_{ij} for $j \neq i$ is, therefore, a means of communication between players, although it is cheap talk.

In a *full agreement game* the strategy set is the same as in a game with communication but the payoff function is different. The public good is provided if and only if total contributions equal or exceed the threshold *and* all players choose the same strategy. This means every player must agree on what every other player should contribute, $c_{ij} = c_{lj}$ for any $i, j, l \in N$.[4] Formally, given strategy profile $(vc_1, \dots, vc_n)$, the payoff of player *i* is

$$u_i(vc_1, \dots, vc_n) = \begin{cases} E_i - c_i + V & \text{if } C \geq T \text{ and } vc_1 = \cdots = vc_n \\ E_i & \text{otherwise} \end{cases} \qquad (2)$$

At the end of the game players are informed on the vector of contributions suggested by each player, and total contributions, as in a game with communication.

[INSERT TABLE 1 AROUND HERE]

We finish this section by introducing some notation and assumptions that will prove useful in the remainder of the paper. Let $m_i = \min\{E_i, V\}$ and let $M = \sum_i m_i$. Informally, we can think of m_i as the maximum that player i can or will be willing to contribute, and M as the maximum that all players can or will be willing to contribute. We shall use $M_{-i} = M - m_i$ and $C_{-i} = C - c_i$ to denote, respectively, the amount that could be and is contributed by players other than i. Finally, we shall assume throughout the following that $M > T$ and $nm_i \geq T$ for all $i \in N$. Thus, it is socially efficient to provide the public good, and players can, if they choose, split the cost of providing the public good equally.

3. Nash equilibria, and focal points

Given that it is socially efficient to provide the public good it is clearly crucial that players collectively contribute the threshold amount, T, or more. Typically, however, there will be many ways to distribute the cost amongst players. This leads to a non-trivial coordination problem with conflict of interest. We begin this section by briefly illustrating how this problem is encapsulated in a multiplicity of Nash equilibria. We then look at whether the existence of a focal point can help players 'resolve the problem' by coordinating on one of the equilibria.

[4] This does not in any way imply symmetry of contributions, i.e. $c_{ij} = c_{il}$.

3.1. Nash equilibria

Consider, first, a standard game, and standard game with feedback. In these games, strategy profile $(c_1, \ldots, c_n)$ is a *Nash equilibrium* if and only if $u_i(c_i, c_{-i}) \geq u_i(c_i', c_{-i})$ for all $c_i' \in S_i$.[5] We say the Nash equilibrium is *strict* if $u_i(c_i, c_{-i}) > u_i(c_i', c_{-i})$ for all $c_i' \in S_i, c_i' \neq c_i$. One can easily derive that strategy profile $(c_1, \ldots, c_n)$ is a Nash equilibrium with public good provision if and only if

$$C = T \quad \text{and } c_i \leq V \text{ for all } i \in N.$$

The payoff of player i is $E_i - c_i + V$. Any, ceteris paribus, change in her strategy would strictly lower her payoff, either to E_i if she decreases her contribution or to $E_i - c_i' + V$ if she increases her contribution to $c_i' > c_i$. The assumption that $M > T$, guarantees the existence of several such equilibria.[6] To illustrate, we refer to Table 2 which introduces three sets of parameters that will be important in the rest of the paper. Strategy profiles $(25,25,25,25,25)$ and $(15,35,25,25,25)$ are two, of many, Nash equilibria that exist with these parameters. Clearly, the first of these equilibria is preferred by player 2, and the second preferred by player 1, and hence a conflict of interest amongst players on how to coordinate (Isaac et al. 1989; Rapoport and Eshed-Levy 1989).

In a game with communication and full agreement game strategy profile $(vc_1, \ldots, vc_n)$ is a Nash equilibrium if and only if $u_i(vc_i, vc_{-i}) \geq u_i(vc_i', vc_{-i})$ for all $vc_i' \in S^{CG}$. In a game with communication strategy profile $(vc_1, \ldots, vc_n)$ is a Nash equilibrium with public good provision if and only if

$$C = T \quad \text{and } c_i \leq V \text{ for all } i \in N.$$

This condition is identical to that in the standard game and standard game with feedback.[7] In the full agreement game strategy profile $(vc_1, \ldots, vc_n)$ is a Nash equilibrium with public good provision if and only if

[5] Where $u_i(c_i, c_{-i})$ denotes the payoff of player i if she contributes c_i and the contributions of others are denoted c_{-i}.

[6] There may exist Nash equilibria with no public good provision, but given that every perfect Nash equilibrium is a Nash equilibrium with public good provision (Bagnoli and Lipman 1989), we shall not dwell on this possibility. To illustrate, strategy profile $(c_1, \ldots, c_n)$ is a Nash equilibrium with no public good provision if and only if

$$C < T \quad \text{and} \quad T - C + c_i > m_i \text{ for all } i \in N.$$

At least one such equilibria will exist if $m_i < T$ for all $i \in N$. In this case, player i receives payoff E_i and no, ceteris paribus, change in her strategy would change her payoff.

[7] The expansion of the strategy space dramatically increases the number of Nash equilibria. This is because a player's suggestion of what others should contribute is irrelevant in determining the Nash equilibrium.

$$C = T \text{ and } c_i \leq V \text{ for all } i \in N \text{ and } vc_i = vc_j \text{ for all } i, j \in N.$$

Clearly, this adds the additional requirement that all players should agree.

Table 2 details the number of Nash equilibria with public good provision in a standard or full agreement game for each set of parameters. Clearly, the number of equilibria is very large. 'Standard' equilibrium refinements do nothing to reduce this number. So, if the problem players' face is to coordinate on a unique Nash equilibrium then they clearly have a potentially tough problem (Isaac et al. 1989). The experimental evidence with regards to the standard type of game confirms this. While groups successfully provide the public good up to 60 percent of the time (Croson and Marks 2000), it is rare to observe a Nash equilibrium. Perhaps more importantly, groups that do play a Nash equilibrium in one round (of repeated interaction) appear no more likely to play a Nash equilibrium in future rounds (Cadsby and Maynes 1999). This likely reflects the desire of at least one player to transition towards a 'better for them' Nash equilibrium. Coordinating on a Nash equilibrium, therefore, is like looking for a needle in a haystack, with the temptation to throw the needle away when you find it in hope of finding a better one. No wonder we observe inefficiency in providing the public good. Or, is there a trick to solving this problem?

[INSERT TABLE 2 AROUND HERE]

3.2. Focal points

We know in general that the existence of a focal point is one means by which players can coordinate on a Nash equilibrium (Schelling 1960). A threshold public good game does have a seemingly obvious focal point, namely, to split the cost of providing the public good equally. We know, however, that split the cost equally is not a good description of how players behave in the standard type of game (e.g. Isaac, Schmidtz and Walker 1989; Suleiman and Rapoport 1992; Croson and Marks 2001; Coats et al. 2009). That leaves the puzzle and challenge discussed in the introduction: why is split the cost not 'focal enough', and is there any way to make it 'more focal'?

To answer these questions it is natural to apply a theory of focal points. In this paper we shall apply the seminal theory of focal points due to Sugden (1995). The theory uses a principle of collective rationality.[8] The basic idea behind collective rationality, or team reasoning, is that a player will recognize a common interest in trying to coordinate on some equilibrium (Sugden 1993; Bacharach 1999). Thus, players look for a decision rule that if followed by all is most likely to produce successful coordination; 'less ambiguous' and 'more obvious' rules should tend to be favoured (Schelling 1960). In order to formally apply the theory we can imagine someone giving advice to each player on how much to contribute, or what vector of contributions to suggest in a threshold public good game.

The advice should consist of a *decision rule* that can be interpreted as a comprehensive plan to play the game; we shall have more to say on this shortly. A *recommendation* $R = (R_1, \ldots, R_n)$ details a decision rule R_i for every player $i \in N$. A recommendation R is said to be *collectively rational* if there exist payoffs $u_1^*, \ldots, u_n^*$ such that (i) if every player $i \in N$ follows her advice R_i then expected payoffs are given by $u_1^*, \ldots, u_n^*$, and (ii) if some player $i \in N$ does not follow her advice R_i then, whatever the decision rule of the other players, the expected payoff of any player $j \in N$ is strictly less than u_j^*.[9] The definition of a collectively rational recommendation is stronger than that of Nash (or correlated) equilibrium in two important respects: it requires that any 'deviation' from the recommendation results in *all* players getting a lower payoff *irrespective* of whether others follow their recommendation. This is a tough condition to satisfy. Tough enough that, in general, there can be at most one collectively rational recommendation and in many games there will be none. Sugden (1995) convincingly argues that if a collectively rational recommendation exists then each player should act on that recommendation. A collectively rational recommendation is thus akin to a focal point of the game.

In a standard game (or standard game with feedback) one can think of a decision rule as a contribution or set of contributions. Thus, $R_i \subset S_i$, and player i is advised to randomly choose a contribution from set R_i. For example, the advice might be 'contribute 25', $R_i = \{25\}$, or 'contribute something between 25 and 35', $R_i = \{25, \ldots, 35\}$. Analogously, in a game with communication or a game with full agreement one can think of a decision rule as a vector of contributions or set of vector of contributions. Thus, $R_i \subset S^{CG}$, and player i is

[8] Gauthier (1975), Bacharach (1993), Casajus (2001) and Janssen (2001) also use variants of the principle of collective rationality.

[9] This definition is a reduced form of the definition given by Sugden (1995). Sugden (1995) allows that advice be conditional on a player's private description of the game and that it can consist of a set of acceptable decision rules. Note also that Sugden (1995) considers a game with two players and we consider the natural extension to more than two players.

advised to randomly choose a vector of contributions from set R_i. For example, the advice might be ‘split the cost equally’

$$R_i^E := \left\{\left(\frac{T}{n}, \dots, \frac{T}{n}\right)\right\}$$

or ‘contribute zero and split the cost amongst others’, which if $i = 1$ gives

$$R_1 = \left\{\left(0, \frac{T}{n-1}, \dots, \frac{T}{n-1}\right)\right\}.$$

Key, at this point, is to explain the information players have about the labels in the game. We can contrast the opposite extremes of common knowledge and a scrambled labelling procedure (Crawford and Haller 1990; Sugden 1995). In either case it is assumed that every player knows the parameters of the game, $n,, E_1, \dots, E_n, T, V$. What may or may not be known are player labels. With common knowledge every player knows which player is ‘player 1’ with endowment E_1, and knows that everyone knows that etc. With a scrambled labelling procedure every player knows that there is a ‘player 1’ with endowment E_1 but they don’t know who that player is. This distinction is most easily explained with an example.

Consider the advice ‘player 1 contributes zero and split the cost amongst others’. In the case of common knowledge this equates to

$$R_i = \left\{\left(0, \frac{T}{n-1}, \dots, \frac{T}{n-1}\right)\right\}.$$

With a scrambled labelling procedure it is ambiguous who player 1 is. The advice is, thus, more appropriately read as ‘let someone else contribute zero and split the cost amongst others’. The advice, therefore, if $i = 1$, equates to

$$R_1 = \left\{\left(\frac{T}{n-1}, 0, \frac{T}{n-1}, \dots, \frac{T}{n-1}\right), \left(\frac{T}{n-1}, \frac{T}{n-1}, 0, \dots, \frac{T}{n-1}\right), \dots, \left(\frac{T}{n-1}, \dots, \frac{T}{n-1}, 0\right)\right\}.$$

The crucial point to recognise is that the scrambling of labels can constrain how specific advice can be. The advice ‘let someone else contribute zero and split the cost amongst others’ is ambiguous because there are $n - 1$ potential candidates for the ‘someone else’.

In order to formalize terms in the context of a standard game we say that strategy profile $(c_1, \dots, c_n)$ is an i-permutation of strategy profile $(c_1', \dots, c_n')$ if there exists a one-to-one mapping $g: N \to N$ such that $c_j = c_{g(j)}'$ and $g(i) = i$. In short, the contribution of player i remains the same while the contributions of all others are potentially swapped around. We say that there is a *scrambled labelling* procedure if any permissible decision rule R_i satisfies the following condition: if $(c_1, \dots, c_n) \in R_i$ and $(c_1', \dots, c_n')$ is an i-permutation of $(c_1, \dots, c_n)$ then $(c_1', \dots, c_n') \in R_i$. We say that there is not a scrambled labelling procedure if any decision rule $R_i \subset S_i$ is permissible. This definition naturally extends to a game with communication and full agreement.

We can now state our main theoretical result. This shows that there exists a collectively rational recommendation if and only if (i) full agreement is required, (ii) labels are scrambled, and (iii) the number of players is sufficiently large. The collectively rational recommendation is to split the cost equally. Intuitively, this is because split the cost equally is unambiguous while other advice is ambiguous. Recall that collective rationality will favour decision rules that are less ambiguous and more obvious.

Theorem 1: There exists a collectively rational recommendation if and only if the game is of the full agreement type, there is scrambled labelling, and

$$\frac{T}{nV} < 1 - \left(\frac{1}{n-1}\right)^{n-1}.$$

When it exists, the collectively rational recommendation is to split the cost equally, $R = (R_1^E, \dots, R_n^E)$.

Proof: Consider a standard game and suppose that $R = (R_1, \dots, R_n)$ is a collectively rational recommendation. Without loss of generality we can assume R_i consists of a single strategy $r_i \in S_i$. Note that it is irrelevant whether labels are scrambled or not. If players follow the recommendation then payoffs are either $u_i^* = E_i - r_i + V$ for all $i \in N$, or $u_i^* = E_i$ for all $i \in N$. Let X denote the set of strict Nash equilibria with public good provision. We know, because $M > T$, that the set X contains at least two equilibria. This means that there exists a strategy profile $(c_1, \dots, c_n) \in X$ that differs from R, in the sense that $c_i \neq r_i$ for at least one player $i \in N$. If players play this Nash equilibrium then payoffs are $u_i' = E_i - c_i + V > E_i$ for all $i \in N$. If $c_i < r_i$ then clearly $u_i' > u_i^*$. If $c_i > r_i$ then either (a) $u_i^* = E_i$ in which case $u_i' > u_i^*$ or (b) there exists some $j \in N$ such that $c_j < r_j$ and $u_j' > u_j^*$. Either way, if players behave according to $(c_1, \dots, c_n)$ rather than R at least one player will receive a strictly higher payoff. This contradicts R being a collectively rational recommendation. A similar argument can be used in a standard game with feedback.

Consider next a game with communication and collectively rational recommendation $R = (R_1, \dots, R_n)$. In this case we can assume, without loss of generality, that R_i consists of a single vector of contributions $R_i \subset S^{CG}$. Consider the recommendation $R_i = (0, \dots, 0, r_i, 0, \dots, 0)$ for all i where each player is 'recommended' to contribute r_i. This recommendation is valid whether labels are scrambled or not. Using the argument of the previous paragraph we see that this cannot be a collectively rational recommendation. The zeros, however, are merely cheap talk and so changing these cannot make any difference. Thus, there does not exist a collectively rational recommendation.

We turn now to a full agreement game in which labels are not scrambled. Consider a collectively rational recommendation $R = (R_1, \dots, R_n)$. Again, we can assume that R_i consists of a single vector of contributions $vr_i \in S^{CG}$. Let X' denote the set of strict Nash equilibria with public good provision. We know that X' contains at least two equilibria. Moreover, because there is not a scrambled labelling procedure any strategy profile $(vc_1, \dots, vc_n) \in X'$ is a permissible decision rule. The argument used for a standard game can now be used again to obtain a contradiction.

Finally, consider a full agreement game with scrambled labelling. Also, consider the recommendation to split the cost equally. If players follow this recommendation then they will play a strict Nash equilibrium with public good provision. Payoffs will be given by $u_i^* = E_i - \frac{T}{n} + V > E_i$ for all $i \in N$. We need to rule out the possibility that a player could expect to do better than this. Without loss of generality we shall attempt to increase the payoff of player 1. To do so, we need that player 1 contributes some amount $\bar{c}_1 < \frac{T}{n}$ and that the public good is provided. The least ambiguous way for others to provide the public good is to split the remaining cost equally. Suppose, therefore, that player 1 uses decision rule

$$R_1 = \left\{ \left(\bar{c}_1, \frac{T - \bar{c}_1}{n-1}, \dots, \frac{T - \bar{c}_1}{n-1} \right) \right\}.$$

The scrambled labelling procedure means that player 2 can only possible agree with player 1 if she uses the decision rule

$$R_2 = \left\{ \left(\bar{c}_1, \frac{T - \bar{c}_1}{n-1}, \dots, \frac{T - \bar{c}_1}{n-1} \right), \left(\frac{T - \bar{c}_1}{n-1}, \frac{T - \bar{c}_1}{n-1}, \bar{c}_1, \dots, \frac{T - \bar{c}_1}{n-1} \right), \dots, \left(\frac{T - \bar{c}_1}{n-1}, \dots, \frac{T - \bar{c}_1}{n-1}, \bar{c}_1 \right) \right\}.$$

The same applies for all $i > 1$. If all players do agree then the payoff of player 1 increases to $E_1 - \bar{c}_1 + V > u_1^*$. If there exists a player j who chooses $vc_j \neq vc_1$ then the payoff of player 1 drops to $E_i < u_i^*$. The probability of full agreement is $\left(\frac{1}{n-1}\right)^{n-1}$ and so the expected payoff of player 1 is greater than u_i^* if and only if

$$E_1 + \left(\frac{1}{n-1}\right)^{n-1} (V - \bar{c}_1) > E_1 - \frac{T}{n} + V.$$

This is ruled out by assumption. Given that we began with the least ambiguous alternative decision rule that could increase the payoff of player 1, split the cost equally is a collectively rational recommendation. ■

Theorem 1 is potentially a very powerful result. It offers a solution to the puzzle of why split the cost equally is not 'focal enough' in a standard game; split the cost is not a collectively rational recommendation and so it is arguably no surprise that groups fail to coordinate or maintain coordination. In addition, Theorem 1 suggests a novel hypothesis on how efficiency can be increased in threshold public good games; if the existence of a collectively rational recommendation helps players to coordinate then a requirement for full agreement may increase efficiency. It's important to be clear exactly what this hypothesis entails: (i) The *direct* effect of full agreement is to make coordination more difficult because all players need to agree. (ii) If the existence of a collectively rational recommendation makes it easier for players to coordinate then full agreement may *indirectly* make coordination easier. This is essentially because the need for agreement makes each players strategy critical. If this indirect benefit outweighs the direct cost then a requirement for full agreement can increase efficiency. We view this as an empirical hypothesis to test, and so we shortly turn to our experimental results.[10] Before doing so we shall look in a bit more detail at the role of endowment asymmetry and scrambling of labels.

A scrambling of labels encapsulates two things, that player identity is private information and that endowment is private information. It seems very natural that player identity be private information; for instance, if players agree on the decision rule 'someone contribute zero and split the cost amongst others' it seems unlikely they would all independently know who the 'someone else' should be. This, in itself, is enough to argue that scrambled labelling is the appropriate thing to consider in symmetric games. In asymmetric games, however, the issue of common knowledge warrants more consideration. To illustrate Table 3 gives some decision rules that are conditional on player endowments.[11] Decision rules 'split the cost proportionally' and 'split the cost so payoffs are fair' are intuitive (van Dijk and Wilke 1993, 1995). They are, however, only possible if player endowments are

[10] The only empirical results we are aware of looking at similar issues are due Van de Kragt, Orbell and Dawes (1983) and Bornstein (1992). In a binary threshold public good game they find that subjects who have agreed with fellow group members how to finance the public good stuck to the agreement. This, however, gives little insight on how group members can successfully reach agreement, particularly in continuous threshold public good games where the task is considerably more difficult. For example, Rauchdobler, Sausgruber and Tyran (2010) find that voting on the size of threshold before playing a threshold public good game makes no difference to efficiency.

[11] See Table 2 for details on the parameters of the symmetric, asymmetric and very asymmetric games.

common knowledge. A scrambled labelling procedure, by making player endowments private information, rules them out.

[INSERT TABLE 3 AROUND HERE]

If recommendations such as 'split the cost proportionally' are permissible then there is no collectively rational recommendation in an asymmetric full agreement game.[12] The intuition for this being that there is no sense in which, say, the equal split is any less ambiguous than the proportional split, according to the definition of a collectively rational recommendation. Whether or not labels are scrambled is, therefore, an important factor in asymmetric games. The applied context under consideration will guide as to the natural assumption to make; in some contexts it may be natural to think of endowments as private information and in others not.

We would argue, however, that even in a context where endowments are theoretically common knowledge agreement on the equal split may be appropriate. To motivate this view, one could consider a weaker notion of collectively rationality and argue that the equal split is 'more obvious' than, say, the proportional split. This, however, seems somewhat ad-hoc and contrary to evidence in the psychology literature (van Dijk and Wilke 1993, 1995).[13] Our preferred view is to say that, even if player endowments are common knowledge, players have an 'incentive' to ignore this information. This would follow from the fact that split the cost equally works irrespective of endowments. Put another way, an expectation that information about endowments may be ignored by at least one player is enough to break common knowledge. We suggest, therefore, that whether or not labels are scrambled depends on both the procedures of the game and the psychology of players.

4. Experimental results

We considered four treatments, with each of the four types of game presented in Table 1 corresponding to a treatment. We reiterate that our standard treatment corresponds to the benchmark treatment used in the threshold public goods literature. The game used in the standard treatment with feedback, communication treatment, and full agreement treatment differ as detailed in Section 2.

[12] In a symmetric game 'split the cost proportionally' and other alternatives are equivalent to split the cost equally.

[13] The argument would be that there is only one way to split the cost equally but lots of ways to split the cost asymmetrically. There is, however, only one way to split the cost proportionally but lots of ways to split the cost non-proportionally. The stronger notion of a collectively rational recommendation avoids such problems.

Each experimental session was divided into three parts, as summarised in Table 4. In part 1, subjects played a game with parameters corresponding to those in the symmetric game, as already detailed in Table 2, for 10 rounds. In part 2 they played a game with parameters corresponding to those in the asymmetric game for a further 10 rounds, and in part 3 they played a game with parameters corresponding to those in the very asymmetric game for a final 10 rounds. The type of game played, standard, standard with feedback, communication or full agreement, was the same in all three parts of a session. Note that subjects retained their role within the group throughout a part. Thus, a subject endowed with, say, 70 in an asymmetric game was endowed with 70 in all 10 rounds.

The groups, of 5, were randomly assigned at the beginning of each part but remained fixed during the part. Fixed matching during each part of the session allows us to look for dynamic and learning effects as observed in previous threshold public good experiments (e.g. Cadsby et al. 2008). The use of three different sets of parameters allows us to consider symmetric and asymmetric games.[14] More specifically, the use of the benchmark parameters in part 1 allows an unambiguous comparison of behaviour across treatments in the standard, symmetric case considered in the literature. Parts 2 and 3 allow us to compare behaviour across treatments as subjects are exposed to progressively more asymmetric endowments. Of primary interest is whether groups coordinate on the equal split even though this becomes increasingly inequitable.

[INSERT TABLE 4 HERE]

Our focus in the experiment was to compare different types of game, and in particular to compare a game with communication to a full agreement game. Even so, it is clearly important, given Theorem 1, to clarify whether labels were scrambled or not. In reality the labels were not scrambled. The instructions given to students, however, used deliberately neutral language. (The instructions, along with a screenshot for the full agreement treatment are available in the appendix.) There was no explicit mention of player labelling or how the game would appear to other members of the group.[15] Following the discussion at the end of the previous section we would argue that this is likely to result in a scrambled labelling

[14] The random matching between parts potentially allows us to treat the success of groups in one part as independent from the success of groups in other parts. We shall not push this claim too far, as it is natural to imagine some learning effects over the 30 rounds. Note, however, that both the group and game change in each part and so a claim of independence is not too extreme. The data analysis will control for part.

[15] No subject asked a question about this.

procedure. The experimental design allows us, therefore, to explore what information groups chose to exploit.

The experiments were run at the University of Kent (UK) with subjects recruited from the general student population. The interactions were anonymous and the experiments were computerized using z-Tree (Fischbacher 2007). We took care to recruit subjects who had not taken part in similar experiments before. We ran 8 sessions in all giving a total of 160 subjects.[16] Subjects were paid in cash at the end of the session an amount equal to their payoff over the 10 rounds multiplied by one pence for one of the three parts. The relevant part was randomly selected for each subject. Each session lasted about 40 minutes and the average payment was £6.13. At the end of each part subjects were asked to fill in a short questionnaire regarding their general experience in the 10 rounds. At the end of part 3 subjects were asked to fill in a further questionnaire. Subjects were not paid for answering the questionnaires but had to answer all of the questions in order to proceed with the experiment. The analysis of the questionnaire responses is beyond the scope of the current paper.

4.1 Hypotheses

The standard game has been extensively studied in the previous literature and so we ‘know’ to expect success rates of around 40-60% (e.g. Croson and Marks 2000). Our first hypothesis is that success at providing the public good will be similar in the standard game with feedback and communication game. This is a natural assumption given that there are no strategic differences between these three games.

Hypothesis 1: The success rate of providing the public good is the same in the standard game, standard game with feedback, and game with communication.

Croson and Marks (1998) compare the standard game and standard game with feedback in a symmetric setting, and find no significant difference in outcomes.[17] We shall extend this by considering asymmetric games and the game with communication. Note, however, that

[16] Note that six sessions were run with 20 subjects, whereas one session involved 25 subjects and another session had 15 subjects.

[17] Our standard treatment corresponds to Croson and Mark’s (1998) group treatment and our standard with feedback treatment corresponds to their individual-identifiable treatment. They also considered a third, individual-anonymous treatment. Significant differences in outcomes were observed between the individual-anonymous treatment and the group and individual-identifiable treatments.

Hypothesis 1 is not our main concern and the standard and standard with feedback treatments were primarily included to check consistency of our results with the previous literature.[18]

Our main hypothesis concerns the comparison between a game with communication and full agreement game. On the basis of Theorem 1 we argue that groups may be better at coordinating in the full agreement game because of the collectively rational recommendation to ‘split the cost equally’.

Hypothesis 2: The success rate of providing the public good in a full agreement game will be higher than that in a game with communication. Groups will agree to split the cost equally.

Hypotheses 1 and 2 together suggest that a requirement of full agreement can increase success rates in threshold public good games. We reiterate that the conditions for providing the public good are much more stringent in a full agreement game than in a game with communication. It is far from trivial, therefore, that Hypothesis 2 will hold. It will only hold if *all* players react to the change in incentives in the way we have predicted.

Our final hypothesis concerns endowment asymmetry. The more asymmetric are endowments the less equitable is split the cost equally. For example in a game with very asymmetric endowments players 1 to 3 get payoff 50 while players 4 and 5 get payoff 125. This creates a tension between the focal point and fairness. Our null hypothesis is that subjects will sacrifice fairness in order to coordinate.

Hypothesis 3: The success rate of providing the public good will be the same in a symmetric, asymmetric and very asymmetric full agreement game.

An alternative to Hypothesis 3 would be to say that when endowments are asymmetric or very asymmetric groups will be less successful at providing the public good. This can occur if those with the smallest endowment ‘reject’ split the cost equally on fairness grounds.

4.2 Summary of results

Table 5 summarizes the success rate at providing the public good in the first five rounds and last five rounds of each treatment in each part. Table 6 summarizes total contributions. [19] The average success rates and average contributions in the standard treatment are consistent with

[18] This is reflected in the relative low number of groups in the standard and standard with feedback treatments. Note, however, that four groups per treatment is not low by the standards of this literature, e.g. Croson and Marks (1998) only consider five groups per treatment.

[19] Notice that, in all four treatments, total contributions are obtained by adding up own contributions as given even if the public good is not provided.

those observed in earlier studies (e.g. Cadsby et al. 2008). Overall, we see similar success rates in the standard, communication and full agreement treatments, with a higher success rate in the standard with feedback treatment. We also see that average contributions are highest in the full agreement treatment and lowest in the communication treatment. Clearly, however, these overall numbers are not capturing the dynamic differences between treatments that seem apparent in Tables 5 and 6.

[INSERT TABLES 5 AND 6 AROUND HERE]

Figure 1 plots the success rate at providing the public good over time in the full agreement treatment and communication treatment (ignore, for now, the FULL HP data). Broadly speaking, the success rate appears stable or decreasing across the 10 rounds of each part in the communication treatment while it is increasing in the full agreement treatment. Indeed, in the first round of the full agreement treatment the success rate is consistently equal to zero; by the end of the ten rounds, the success rate reaches the relatively high level of 75 percent in parts 1 and 3 and 67 percent in part 2. It is also noteworthy that the success rate appears stable or decreasing across the three parts in the communication treatment while it is stable in the full agreement treatment.[20] This contributes to the success rate in the full agreement treatment being relatively low in part 1 and relatively high in part 3.

[INSERT FIGURE 1 AROUND HERE]

4.3 Success rates

To test whether there were significant differences between treatments in terms of success rate, we report results of a random-effects probit regression with the probability of success as the dependent variable. The communication treatment was used as comparator. This directly allows us to test whether success was higher in the full agreement treatment than in the communication treatment (Hypothesis 2) and whether success was the same in the communication treatment as in the standard treatments (Hypothesis 1). Four non-interactive independent variables are used, round number and a dummy variable for the three remaining treatments. To more fully account for possible dynamic effects we also use three interactive independent variables, round crossed with treatment. Table 7 summarizes the results.

[20] The standard treatments are omitted from figure 1 to avoid cluttering the figure. The success rate is also stable or decreasing in each part and across the three parts.

[INSERT TABLE 7 AROUND HERE]

The results in Table 7 confirm an increasing success rate in the full agreement treatment in all parts. By contrast, in part 1, the success rate is decreasing in the other three treatments; in part 2, it is increasing in the standard treatment but stable in the standard with feedback and communication treatments; in part 3, it is stable in the other three treatments. This is clear evidence of the dynamic effect, previously noted, in which there is a tendency for the success rate to increase in the full agreement treatment and not in the communication treatment. There is also no evidence of a substantial difference in the dynamics of the success rate between the communication treatment and the standard treatments.

The above dynamic effect needs to be weighed against the negative coefficient on the dummy variable for the full agreement treatment. The end result is a prediction of lower success rates in the full agreement treatment in earlier rounds but higher success rates by later rounds. By the end of part 3, for example, success rates are predicted to be 95.2 percent in the full agreement treatment compared to 19.3 percent in the communication treatment and 46.6 and 59.3 percent in the standard and standard with feedback treatments; the difference between the full agreement and coordination treatment is highly significant ($p < 0.001$).

The data we have reviewed so far is consistent with Hypothesis 1 in that there is no strong evidence of any significant difference between the two standard treatments and the communication treatment. It is also consistent with Hypothesis 3 in that there is no evidence of a difference in success in the full agreement treatment because of asymmetry. Evaluating Hypothesis 2 is a little trickier. One might have hoped that groups would be able to successfully coordinate in round 1 of the full agreement treatment. Clearly, that did not happen. With experience, however, success rates in the full agreement treatment were high, and significantly higher than in the communication treatment. This provides some support for Hypothesis 2. But, it also suggests we need to look a little bit deeper at how groups were able to learn to successfully provide the public good.

4.4 Coordinating over time

As well as giving the actual success rates in the full agreement and coordination treatments, Figure 1 shows the success rate that would have been achieved in the full agreement treatment if the rules for the provision of the public good had been the same as in the communication treatment (the FULL HP line). Observe that success rates would have been very high, especially in parts 1 and 2. This tells us that very different things are causing inefficiency in the full agreement treatment compared to the communication treatment. In the communication treatment we know that any failure to provide the public good must be caused by the total contribution being insufficient. In the full agreement treatment it is clear that failure to provide the public good was primarily caused by a lack of agreement, and not the total contribution being insufficient. This allows us to reconcile the high contributions we observe in Table 6 with the not so high success rate in Table 5.

Figure 1 suggests that increasing success in the full agreement treatment reflects groups learning how to coordinate. One way to capture this learning effect is to look at whether group success is permanent or temporary. We know, as already discussed above, that success in the standard treatment tends to be temporary, i.e. success in one period says little about success in subsequent periods. If groups in the full agreement treatment are learning how to coordinate then we would expect success to be more permanent, i.e. once the group finds how to coordinate they will stick with it. Such a difference between the full agreement and coordination treatment would be consistent with Theorem 1 and the notion of collective rationality, provided that groups learn to coordinate on split the cost equally.

We find evidence that group success is more permanent in the full agreement treatment. For instance, in the full agreement treatment, 19 out of the 36 groups successfully provide the public good in every round after their first success; this meant sustaining success for an average of 5.6 out of ten rounds.[21] In the communication treatment, only 5 out of the 36 groups sustained successful provision; they did so for an average 4.6 rounds. Such a difference is statistically significant (likelihood ratio test, $p < 0.001$). Also, in the full agreement treatment, initial success was maintained for an average of 4.4 rounds compared to only 3.5 rounds in the communication treatment. This difference is only marginally significant (Mann-Whitney, $p = 0.1$) but is so despite the data for the full agreement treatment being highly censored by the ten round cut off.[22]

It remains to question whether groups coordinated on the collectively rational recommendation of split the cost equally. Figure 2 details individual choices in round 10 of each part. We distinguish choices into three categories: split the cost equally, symmetric but inefficient choice, e.g. vector of contributions (30,30,30,30,30), and any non-symmetric choice. In the full agreement treatment the vast majority of choices are symmetric, and the

[21] We have aggregated over all parts given no observed differences between parts. For example, the respective numbers are 6 out of 12 groups in part 1, 7 in part 2 and 6 in part 3.

[22] We have no idea how long the 19 groups who successfully sustained provision up to period 10 could have continued to maintain their success.

majority of these choices are split the cost equally. Interestingly, however, groups did successfully coordinate on alternatives to split the cost equally. For example, in part 1 we saw groups coordinate on (30,30,30,30,30) and (40,40,40,40,40); in part 2 we saw groups coordinate on (15,15,15,40,40) and (19,19,19,34,34); in part 3 we saw one group coordinate on (9,9,9,49,49). This shows that some groups used information about endowments. Overall, however, it is clear that split the cost equally was the predominant choice.

[INSERT FIGURE 2 AROUND HERE]

The predominance of split the cost equally in the full agreement treatment is consistent with Hypothesis 3. Indeed, when endowments were very asymmetric, all bar one of the groups that successfully coordinated used split the cost equally. We know that split the cost equally is considered unfair (van Dijk and Wilke 1993, 1995). So, we see strong evidence that subjects were willing to sacrifice equity in order to coordinate on the focal point. As discussed in the introduction this finding is consistent with recent results by Isoni et al. (2013) and points to the power of focal points in asymmetric games.

5. Conclusions

Many public goods can be implemented as threshold public goods and so it is very important to question whether such goods can be provided efficiently. The experimental evidence to date suggests that inefficiency is to be expected. In this paper we offer an explanation for this inefficiency and a potential solution. To explain the inefficiency we show that in a standard threshold public good game there is no collectively rational recommendation. This means that there is no 'easy way' for group members to agree on how to split the cost of providing the public good. In offering a solution we show that if full agreement is required to provide the public good then there is a collectively rational recommendation. That recommendation is to split the cost equally.

In applied settings it is not uncommon to see a requirement for full agreement before public goods are provided. For instance, we see it in political settings where agreement is required for new treaties or policy, and in capital fundraising projects where conditional donations are common. It is important to recognise, however, that a requirement of full agreement has the direct effect of making it more difficult for the group to provide the public good. *All* group members need to agree. It is, thus, an empirical question whether a requirement of full agreement is a help or hindrance for groups. We reported experimental results to explore this question. These results show that when group members first interacted, the requirement for full agreement led to significantly decreased efficiency; this reflects the difficulty of all members reaching agreement. With experience, however, efficiency increased when full agreement was required, and increased to relatively high levels; success was also more lasting.

Our theoretical and experimental results provide evidence that a requirement for full agreement can increase efficiency. The indirect benefit of increased criticality overcomes the direct cost of requiring agreement. As group size increases and the benefits of the public good become highly asymmetric we may find situations in which it does not make sense to require all group members agree. Instead, it may be more appropriate to require some level of agreement below full agreement. Indeed, there may be an optimal level of agreement required in order to trade-off the benefit of increased criticality with the difficulty of getting many to agree. It may also be appropriate to consider rounds of cheap talk before a decision has to be made, and to allow side-payments between players that have highly asymmetric endowments. These are issues that can be explored in future work. The current paper demonstrates the importance of exploring agreement and conditional contributions in more detail.

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Table 1: Comparison of the four games we consider.

Type of game	Feedback	Strategy set	Public good provided
Standard	Total contributions.	Own contribution.	Achieve threshold
Standard with feedback	Individual contributions	Own contribution	Achieve threshold
With communication	Individual vectors of contributions	Vector of contributions	Achieve threshold
Full agreement	Individual vectors of contributions	Vector of contributions	Achieve threshold and all agree on a vector of contributions

Table 2: The games used in the experiment, and the number of Nash equilibria.

	Parameters of the game					Number of Nash equilibria
	n	Endowment		*V*	*T*	
		Players 1-3	Players 4-5			
Symmetric	5	55	55	50	125	4,052,751
Asymmetric	5	45	70	50	125	3,075,111
Very asymmetric	5	25	100	50	125	254,826

Table 3: Decision rules in the games we consider.

Decision rule	Benchmark	Asymmetric	Very asymmetric
Equal split	(25,25,25,25,25)	(25,25,25,25,25)	(25,25,25,25,25)
Proportional split	(25,25,25,25,25)	(21,21,21,31,31)	(11,11,11,46,46)
Fair split	(25,25,25,25,25)	(15,15,15,40,40)	(0,0,0,62.5,62.5)

Table 4: Experimental design.

Session	Treatment (Type of game)	Part 1 Rounds 1-10	Part 2 Rounds 11-20	Part 3 Rounds 21-30	No. of groups per part
5	Standard	Symmetric	Asymmetric	Very asymmetric	4
2	Standard with feedback	Symmetric	Asymmetric	Very asymmetric	4
3, 6, 7	Communication	Symmetric	Asymmetric	Very asymmetric	12
1, 4, 8	Full agreement	Symmetric	Asymmetric	Very asymmetric	12

Table 5: Success rates over the ten rounds of each part.

	Success rate for provision %									
	Part 1			Part 2			Part 3			Overall
Treatment	First five	Last five	All	First five	Last five	All	First five	Last five	All	All
Standard	55	40	47.5	40	75	57.5	25	50	37.5	47.5
Standard with feedback	90	60	75	80	60	70	55	55	55	66.7
Communication	73.3	53.3	63.3	50	53.3	51.7	33.3	28.3	30.8	48.6
Full agreement	16.7	53.3	35	21.7	66.7	44.2	36.7	73.3	55	44.7

Table 6: Group contributions over the ten rounds.

	Average group contribution									
	Part 1			Part 2			Part 3			Overall
Treatment	First five	Last five	All	First five	Last five	All	First five	Last five	All	
Standard	133.5	123.8	128.6	128	134.4	131.2	109	119.3	114.2	124.7
Standard with feedback	156.3	131.8	144.1	134.5	126.9	130.7	126.3	122.7	124.5	133.1
Communication	139.1	122.4	130.7	125	128.9	126.9	108.7	98.25	103.5	120.4
Full agreement	165.7	159.5	162.6	154.3	151.4	152.9	124.4	121.3	122.8	146.1

Table 7: Results of a random-effects probit regression of the probability of success, round number (Round), treatments (FULL, STF, ST), and interactions between round number and treatments (FULL_Round, STF_Round, ST_Round). Standard errors in brackets; * indicates significant at the 10% level, ** at the 5% level, and *** at the 1% level.

Covariate	Part 1	Part 2	Part 3
Round	-0.158*** (0.048)	-0.020 (0.045)	-0.011 (0.050)
FULL	-3.572*** (0.590)	-2.534*** (0.642)	-0.947 (0.668)
STF	0.097 (0.722)	0.474 (0.761)	0.791 (0.854)
ST	-1.050 (0.658)	-1.193 (0.785)	-0.240 (0.916)
FULL_ Round	0.460*** (0.078)	0.393*** (0.083)	0.348*** (0.082)
STF_ Round	0.041 (0.093)	0.008 (0.089)	0.031 (0.088)
ST_ Round	0.098 (0.085)	0.248** (0.096)	0.102 (0.100)
Constant	1.316*** (0.364)	0.176 (0.385)	-0.754 (0.466)
# Obs.	320	320	320
# Groups	32	32	32

Figure 1: Success rate in the communication treatment (COMM), full agreement with treatment (FULL), and full agreement treatment if we remove the condition that all players must agree (FULL HP).

Figure 2: Choices in round 10 of each part distinguished by whether the group was successful or not in providing the public good.

Appendix

A. Instructions for the standard treatment and standard treatment with feedback

In this experiment you will make decisions, and earn an amount of money that depends on what you and others choose. The money will be given to you at the end of the experiment. Only you will know how much money you earned.

The session will be divided into 3 parts. Each part will last for 10 periods. In each part you will be organised into groups of 5.

In each period you will receive a certain number of tokens. You will be asked to say how many tokens you want to allocate to a group account. The other four people in the group will do the same. If the sum of tokens that each person allocates is greater than or equal to 125 then you all receive an additional 50 tokens.

So, your payoff for the period is:

If the sum of tokens allocated to the group account ≥ 125

payoff = initial number of tokens – tokens allocated to group account + 50

If the sum of tokens allocated to the group account < 125

payoff = initial number of tokens

As we said earlier, the experiment will consist of 3 parts of 10 periods each. In each part of the experiment the 5 people in your group will stay the same and the amount of tokens initially given to each person will stay the same. In each different part of the experiment there will be different people in your group and the amount of tokens initially given to each person will change. This will be indicated on your computer screen.

At the end of each part, you will be asked to fill in a short questionnaire.

Your total earnings will depend on your decisions in the 10 periods. You will be paid in cash the total amount that you earned for one of the three parts in the session. Each token will be worth 1p.

B. Instructions for the communication treatment

In this experiment you will make decisions, and earn an amount of money that depends on what you and others choose. The money will be given to you at the end of the experiment. Only you will know how much money you earned.

The session will be divided into 3 parts. Each part will last for 10 periods. In each part you will be organised into groups of 5.

In each period you will receive a certain number of tokens. You will be asked to say how many tokens you think each person should allocate to a group account. That is, you should say how many tokens you want to allocate for yourself, and how many tokens you think each of the other four people in the group should allocate. The other four people in the group will do the same. If the sum of tokens that each person allocates for him or herself is greater than or equal to 125 then you all receive an additional 50 tokens.

To illustrate, consider this example (**and it is just an example with arbitrary numbers**) where each person is allocated 70 tokens. Person 1 is saying that he or she should allocate 50 tokens to the group account, person 2 should allocate 40 tokens, and so on. In this case they will receive the additional 50 tokens because the sum of tokens each person allocates for him or herself (person 1 allocates 50, person 2 allocates 10, person 3 allocates 30, person 4 allocates 40 and person 5 allocates 20) is greater than 125.

	How much each person should allocate to the group account				
	Person 1	Person 2	Person 3	Person 4	Person 5
Person 1	50	40	60	20	10
Person 2	30	10	60	40	30
Person 3	30	30	30	30	30
Person 4	30	10	60	40	30
Person 5	40	30	10	30	20

To summarize: Your payoff for the period is:

If the sum of tokens each person allocates for him or herself to the group account ≥ 125

payoff = initial number of tokens – tokens allocated to group account + 50

If the sum of tokens allocated to the group account < 125

payoff = initial number of tokens

As we said earlier, the experiment will consist of 3 parts of 10 periods each. In each part of the experiment the 5 people in your group will stay the same and the amount of tokens initially given to each person will stay the same. In each different part of the experiment there will be different people in your group and the amount of tokens initially given to each person will change. This will be indicated on your computer screen.

At the end of each part, you will be asked to fill in a short questionnaire.

Your total earnings will depend on your decisions in the 10 periods. You will be paid in cash the total amount that you earned for one of the three parts in the session. Each token will be worth 1p.

C. Instructions for the full agreement treatment

In this experiment you will make decisions, and earn an amount of money that depends on what you and others choose. The money will be given to you at the end of the experiment. Only you will know how much money you earned.

The session will be divided into 3 parts. Each part will last for 10 periods. In each part you will be organised into groups of 5.

In each period you will receive a certain number of tokens. You will be asked to say how many tokens you think each person should allocate to a group account. That is, you should say how many tokens you want to allocate for yourself, and how many tokens you think each of the other four people in the group should allocate. The other four people in the group will do the same. If everyone in the group says the same thing, and the sum of tokens that each person allocates is greater than or equal to 125, then you all receive an additional 50 tokens.

To illustrate, consider this example (**and it is just an example with arbitrary numbers**) where each person is allocated 70 tokens. Person 1 is saying that he or she should allocate 50 tokens to the group account, person 2 should allocate 40 tokens, and so on. In this case they will not receive the additional 50 tokens because they do not all say the same thing. Person 2 and 4 do say the same thing but it is necessary for all five to agree in order to receive the extra 50 tokens.

	How much each person should allocate to the group account				
	Person 1	Person 2	Person 3	Person 4	Person 5
Person 1	50	40	60	20	10
Person 2	30	10	60	40	30
Person 3	30	30	30	30	30
Person 4	30	10	60	40	30
Person 5	40	30	10	30	20

To summarize: Your payoff for the period is:

If everyone says the same thing, and the sum of tokens allocated to the group account ≥ 125

payoff = initial number of tokens – tokens allocated to group account + 50

If some do not say the same thing and/or the sum of tokens allocated to the group account < 125

payoff = initial number of tokens

As we said earlier, the experiment will consist of 3 parts of 10 periods each. In each part of the experiment the 5 people in your group will stay the same and the amount of tokens initially given to each person will stay the same. In each different part of the experiment there will be different people in your group and the amount of tokens initially given to each person will change. This will be indicated on your computer screen.

At the end of each part, you will be asked to fill in a short questionnaire.

Your total earnings will depend on your decisions in the 10 periods. You will be paid in cash the total amount that you earned for one of the three parts in the session. Each token will be worth 1p.

D. Screen shot for the full agreement treatment